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Wong et al.

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(54) **SIMULTANEOUS FORWARD LINK BEAM FORMING AND LEARNING METHOD FOR MOBILE HIGH RATE DATA TRAFFIC**

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(51) **Int. Cl.**[7] **H04B 1/38**

(52) **U.S. Cl.** **455/562**; 455/561; 455/517

(58) **Field of Search** 455/561, 562, 455/517, 512, 525; 370/334, 329, 338, 347, 349, 468, 252

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(57) **ABSTRACT**

Disclosed is a base station of a wireless communications system including an adaptive antenna array and beam forming means for forming simultaneous multiple forward link beams. Preferably mobile stations are separated into groups of mobile stations corresponding to a maximum number of simultaneous forward link beams for determining which of said groups can be served by compatible simultaneous forward link beams. Preferably, if mobiles remain outside of a compatible group, the number of simultaneous forward link beams is increased and grouping of the mobile stations is repeated until all the mobile stations are included in compatible groups. Preferably simultaneous data beams are formed to mobiles of a said group during a time interval accorded to said group, such that every mobile station receives service data during a full cycle of said time intervals at a rate equal to or in excess of a target service data rate for that mobile.

20 Claims, 6 Drawing Sheets

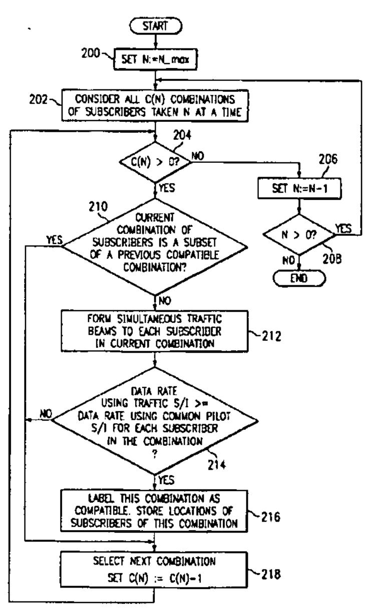
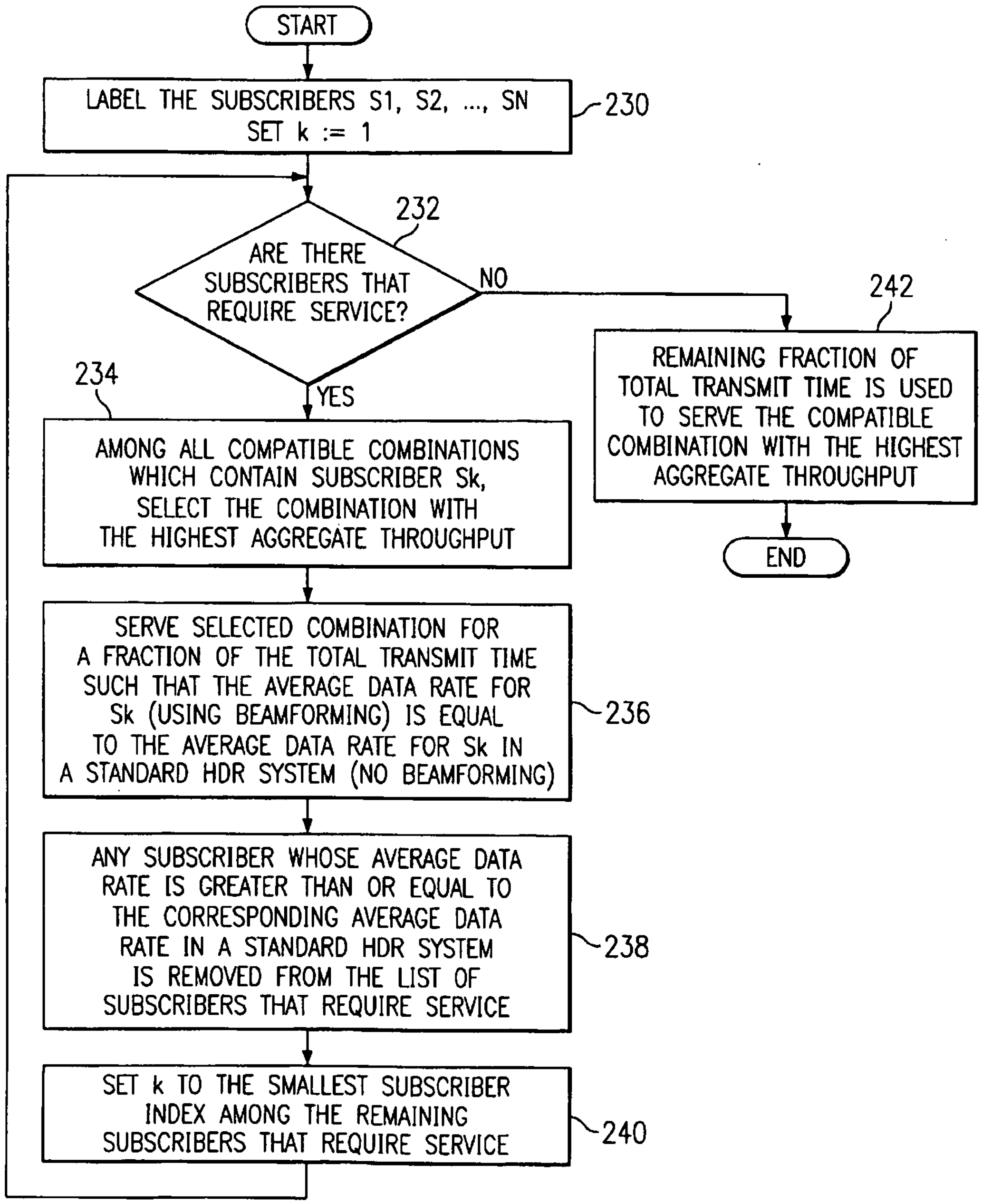


FIG. 9


START
LABEL THE SUBSCRIBERS S1, S2, ..., SN
SET k := 1
230
232
ARE THERE SUBSCRIBERS THAT REQUIRE SERVICE?
NO
YES
242
REMAINING FRACTION OF TOTAL TRANSMIT TIME IS USED TO SERVE THE COMPATIBLE COMBINATION WITH THE HIGHEST AGGREGATE THROUGHPUT
END
234
AMONG ALL COMPATIBLE COMBINATIONS WHICH CONTAIN SUBSCRIBER Sk, SELECT THE COMBINATION WITH THE HIGHEST AGGREGATE THROUGHPUT
SERVE SELECTED COMBINATION FOR A FRACTION OF THE TOTAL TRANSMIT TIME SUCH THAT THE AVERAGE DATA RATE FOR Sk (USING BEAMFORMING) IS EQUAL TO THE AVERAGE DATA RATE FOR Sk IN A STANDARD HDR SYSTEM (NO BEAMFORMING)
236
ANY SUBSCRIBER WHOSE AVERAGE DATA RATE IS GREATER THAN OR EQUAL TO THE CORRESPONDING AVERAGE DATA RATE IN A STANDARD HDR SYSTEM IS REMOVED FROM THE LIST OF SUBSCRIBERS THAT REQUIRE SERVICE
238
SET k TO THE SMALLEST SUBSCRIBER INDEX AMONG THE REMAINING SUBSCRIBERS THAT REQUIRE SERVICE
240

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TITLE: Simultaneous forward link beam forming and learning method for mobile high rate data traffic

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Brief Summary Text - BSTX (6):

The CDMA air-interface calls for modulation of each carrier with a unique pseudorandom (pseudo-noise) code. As the CDMA users simultaneously occupy the same frequency band, the aggregate **data signal transmitted** by a fixed base station (forward link) is noise-like. A common pilot tone is transmitted to all mobiles within the effective service area of the base station. Individual signals are extracted at the mobile by correlation processing timed by the pilot tone.

Brief Summary Text - BSTX (12):

As shown in FIG. 1 forward link **packet transmissions** are time-multiplexed and transmitted at a full base station power level, but with data rates and time slot durations which vary according to base-to-mobile (user) channel (forward link maximum data rate) conditions. When a mobile's data queue is empty, the base station periodically broadcasts very brief pilot and control burst information, thereby reducing interference to adjacent cells. In the proposed HDR scheme, a minimum data rate is set at 76.8 kbps using 128 byte packets and QPSK **modulation, and a maximum data rate** is set at 2457.6 kbps using 512 byte packets and 16QAM modulation.

Detailed Description Text - DETX (8):

The beam forming strategy in accordance with the present invention is to form as many simultaneous beams within each time slot as possible of a sector service cycle, since an increase in the number of simultaneous beams increases the aggregate data throughput rate of the service sector, e.g., exemplary sector SS1. As shown in FIG. 4, each simultaneously formed **beam most preferably has a beam width** BW which envelopes the recipient mobile and provides a tolerance or operating range to provide continuing service as the mobile moves through the particular service sector SS.

Detailed Description Text - DETX (15):

At lower data rates a robust four level modulation format, such as quadrature phase shift keying (QPSK), is preferred. At high data rates it is practical to use a larger constellation modulation format, such as 8-level PSK or 16-level quadrature amplitude modulation (QAM). At the **higher data rates** it is important to maintain the dedicated pilot at a minimum effective level. Thus, as shown in FIG. 7, the dedicated pilot power level falls at a relatively steep rate in relation to increasing data **rate for QPSK modulation,** and thereafter falls at a much more shallow rate in relation to increasing data **rate for 8 PSK modulation** and 16 QAM.

Detailed Description Text - DETX (18):

Combinations of mobiles suitable for receiving simultaneous transmission are determined based on the locations and data rates of the particular mobile stations relative to the base station (the base station accurately determines angle and radius for each mobile as part of the reverse link and forward link beam forming process). Particular results depend on the actual propagation environments and parameters applicable to each particular service sector. A combination of mobiles is said to be "compatible" for simultaneous **transmission if the data** rate achievable with the particular combination is equal to or greater than the data rate achievable using a common pilot, conventional HDR data rate without simultaneous beam forming for each mobile of the combination. In this regard, compatible combinations which are subsets of other compatible combinations are discarded as unnecessary. In statistically rare circumstances a compatible combination might comprise a single active mobile station, in which case the aggregate data rate for such a single unit group would equal the conventional HDR data rate.

Detailed Description Text - DETX (24):

In the conventional HDR method, a maximum of 29 mobiles can be served at any given time within a service sector of a CDMA wireless communications system. In order that the new method provide a data rate for every mobile which is at least equal to the conventional HDR data rate, the base station first considers a first mobile presently having the lowest data rate, and considers all compatible combinations which include this first mobile, picking the combination which results in the highest aggregate data throughput. The selected combination is served for a fraction of the total **transmit time such that the average data** rate for the first mobile is at least equal to the data rate of the conventional HDR system. While this first mobile receives forward link data at a rate not less than the conventional HDR data rate, the other mobiles within the combination receive forward link data at data rates well in excess of the conventional HDR base line rate. This method achieves a desired high base station aggregate data throughput for this particular combination. Then, a second mobile having the next lowest data rate and which is not a member of the first combination is considered along with other mobiles awaiting service by the base station, and a combination which results in the highest base station aggregate data throughput is selected. The second mobile and the other mobiles of the second combination receive forward link data transfers during a second slot which represents another fraction of the total transmit time sufficient to enable the second mobile to receive forward link data at or above the base line conventional HDR data rate. This process of forming compatible combinations and sending forward link data to the mobiles of each combination during fractions of total transmit time continues until all mobiles within the service sector have been serviced.

Detailed Description Text - DETX (25):

After all of the mobiles have been grouped into compatible combinations and serviced via simultaneous beams as explained above, a fraction of total transmit time will typically remain available for further use. One approach may be to use the remaining time to serve the combination of mobiles having the highest aggregate data throughput. This approach will result in the highest overall service sector aggregate data rate, and some mobiles will receive data at exceptionally high data rates. An alternative approach which results in lower overall aggregate data rate, but which more equitably services all mobiles is to serve each compatible combination in proportion to the fraction of time previously given to that combination. Within the conventional HDR approach, mobiles closer to the base station typically receive data at the

highest data rates. In contrast to conventional HDR, in the approach of the present invention not only do the mobiles closer to the base receive **higher aggregate data rates,** but also the mobiles which may be more distant from the base station receive **higher aggregate data rates,** depending upon their angle and distance from the base station as explained above.

Detailed Description Text - DETX (33):

Table 1 presents data from a simulation using beam forming with a dedicated pilot. The path loss exponent is a quantification of path loss between the base station and the mobile station. The standard deviation of the lognormal shadowing represents a shadowing parameter between the base station and the mobile station. The angle spread range represents assumed angle spread at the mobile station, with an angle range of 10.degree. to 60.degree. conservatively assumed for stations close to the base station, and a range of 0.degree. to 30.degree. aggressively assumed for stations at a relatively distant location relative to the base station. The next column, HDR throughput represents a standard base line data throughput for the assumed conditions based on the conventional HDR standard. This forms a base line with a latency ratio of 5. The next column, Gain AAA(1) represents data throughput gain in accordance with the new method in which remaining time is given to the best combination. In the first row example the data rate gain is 3.4 times the base rate of 563 kbps. Since some mobiles will get significantly **higher data rates** when the remaining time is given to the best compatible combination over comparable mobiles within a conventional HDR paradigm, the latency ratio becomes very high, e.g., 112. When the second method (2) is used for allocating excess time equitably across all compatible combinations, rather than solely to the fastest compatible combination (1), the first row examplary data rate gain is 3 times greater than conventional HDR and the latency ratio falls to 82, denoting more equity in distribution of service among all of the mobiles being serviced in the service sector.